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Recycle Paper — An Overview

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## RECYCLE PAPER - AN OVERVIEW

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### ABSTRACT

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Paper and paperboard account for 63% of all recovered materials, including metal, glass, and plastic. In 1993, for the first time in U.S. history, as much paper was recovered as was landfilled. In 1994, the recovery rate for paper and paperboard exceeded 40% of consumption. The recovery goal is 50% by the year 2000.

The increasingly high prices of virgin pulp is encouraging the U.S. Paper Industry to resort more and more to alternate fiber sources such as recycle paper. The biggest source of recycle papers is old corrugated containers (OCC), followed by old newspapers (ONP). The biggest users of recycle paper and paper board are containerboard, recycle paperboard, newsprint, tissue, and printing grades. There is an increasing demand for mixed papers from mixed office waste (MOW), residential curbside collection, and post-industrial waste.

The major barriers to the use of recycle paper are contaminants, which include stickies and short fiber lengths (fines). Successive recycles of wood fiber continually decrease their quality for papermaking. Process and chemical strategies are being developed to deal with the barriers. The major process steps for recycling paper are pulping, screening, cyclic cleaning, flotation deinking, washing, thickening, and dispersion. Chemical strategies are being developed to negate the effects of stickies, to maintain drainage with increased levels of fines, and to enhance the bonding qualities of recycled fibers.

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### INTRODUCTION

In 1994, total recovery of paper in the United States approached 39 million tons (1), almost doubling in the ten years since 1984 ( 20.5 million tons). This represents a 1994 recovery rate of over 40% vs. 27% in 1984. The U.S. goal is for a recovery rate of 50% in the year 2000. 1993 was the first year in U.S. history where the recovery of paper exceeded the amount sent to landfills. Over 75% of U.S. recovered paper is recycled for consumption in domestic paper and paperboard mills. The rest is consumed in other uses or exported.

The American Forest & Paper Association (AF&PA) maintains annual statistics on five broad categories of recovered paper (2). These categories, with 1994 recovery and domestic consumption quantities, are reported below.

<u>Grade</u>	<u>1994 Recovery, (1,000 tons)</u>	<u>U.S. Consumption (1,000 tons)</u>
Corrugated	17,909	14,534
Newspapers	7638	6,294
Mixed Papers	5,612	4,341
Pulp Substitutes	3,723	2,963
High Grade Deinking	3,783	3,081

AF&PA (2) identifies these grades as follows:

**Corrugated** - Old containers both corrugated and solid fiber, container plant cuttings, kraft paper and bags, kraft bag clippings, carrier stock and carrier stock clippings. ISRI grades 11-21.

**Newspapers** - Old newspapers, special news (including deink quality), over-issue news, white blank news, groundwood computer printout, publication blanks, mixed groundwood and flyleaf shavings, and coated groundwood sections. ISRI grades 6-9, 24-26, 44.

**Mixed Papers** - Mixed papers, super mixed papers, office papers (if not deinked or of suitable quality to be used as a pulp substitute), magazines and catalogues, telephone directories, recycled boxboard cuttings, tissue paper converting scrap) if predominantly composed of recycled fiber), mill wrappers, specialty grades, and all other grades not elsewhere specified. ISRI grades 1-5, 10, 22, 23, 27, and 1S-33S.

**Pulp Substitutes and High Grade Deinking** - Includes bleached chemical grade office papers and computer printout to be deinked or of suitable quality to be used as a pulp substitute, bleached sulfite and sulfate cuttings including tissue paper converting scrap (if predominantly composed of bleached chemical pulp fiber), and coated book stock. Print free grades are reported as Pulp Substitutes and printed grades, if deinked, are reported as High Grade Deinking. ISRI grades 28-43, 45-51.

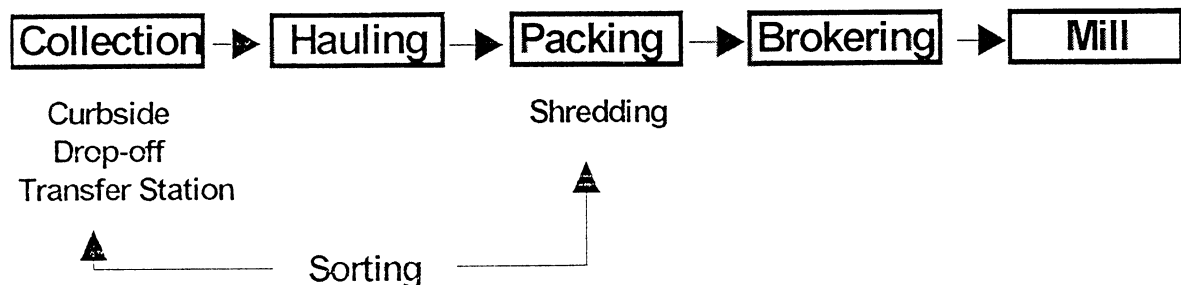
The Paper Stock Institute (PSI) (3) defines 51 grade categories (5 grades not currently in use) of secondary paper stock. In addition they list 33 specialty grades. Attachment I lists the PSI grades and cross references to grade codes of the AF&PA.

The major sources of recycle paper are pre-consumer waste, office waste, and residential curbside waste. Pre-consumer waste, which includes post-industrial waste, is that waste generated at commercial establishments, for example, corrugated boxes from supermarkets or trim and clippings from box plants.

Figure 1 is a simple flow diagram of recycle paper distribution. Collection may occur from curbside, a drop-off point such as might exist for apartments, or a transfer station. Generally, recycle paper is transported to a packer, where it is packed into wire-bound bales. The packing operation may include other operations such as shredding. A broker arranges shipment of the recycle bales to a recycle mill. The type of recycle paper shipped to any particular mill is based on price, quality, and the particular needs of that mill. The flow diagram of Figure 1 is not fixed and will vary from location to location. For example, there are some recycle paper mills that act as their own brokers. These mills may provide drop-off points right on their own sites and do their own packing. They may also serve as distributors for subordinate mills within the organization.

An important development in recent years has been the concept of the "mini mill." These are relatively small paper mills based on 100% recycle paper and located near large urban centers to take advantage of the large amounts of recycle paper being generated. This is in contrast to virgin fiber mills which are often located in remote forest areas and far away from recycle sources.

**Figure 1. Recycle Paper Distribution**



Inherent in the paper distribution process is a sorting operation. Sorting may take place at a number of points in the recycle path including collection points. In some localities residents sort their garbage by putting old newspapers in a separate recycle bin for collection. Often, sorting is done at the packing operation. This is usually a conveyor operation where assigned people remove designated materials from the recycle stream.

There are two types of sorting. **Positive Sort** removes and segregates more valuable materials, such as old corrugated container (OCC), from a recycle stream. **Negative Sort** removes objectionable materials from the recycle stream. Positive Sort downgrades the quality of the stream, whereas negative sort upgrades the quality. In recent years mixed waste or mixed paper has become significant as an alternate fiber source in recycle mills. Very often, this is what is left over from a positive sort.

## QUALITY CRITERIA AND CONCERNS

PSI specifies secondary paper by outthrows, prohibitives, and sometimes by groundwood content. **Outthrows** and **prohibitives** are defined as follows:

Outthrows : All papers that are so manufactured or treated or are in such a form as to be unsuitable for consumption as the grade specified.

Prohibitives :

- a. Any materials which by their presence in a packing of paper stock, in excess of the amount allowed, will make the packaging unusable as the grade specified.
- b. Any materials that may be damaging to equipment.

A bale test is the method to determine outthrows and prohibitives in a recycle lot. This involves tearing the bale, sorting the components, and weighing the sorts, including those identified as outthrows and prohibitives.

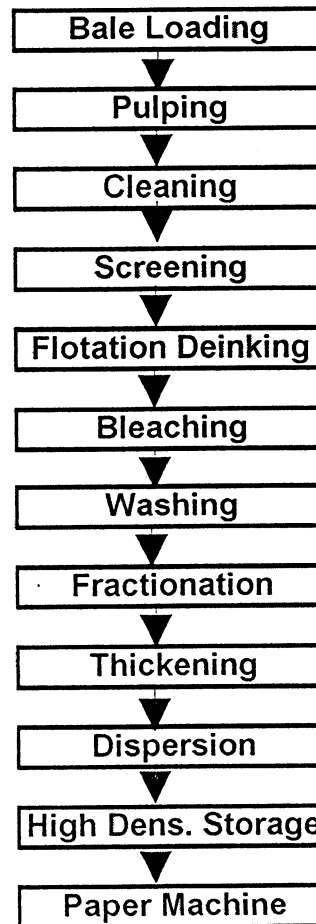
In addition to outthrows and prohibitives, other quality concerns that have to be considered in waste recycle streams are fiber composition, fiber length, ash content, and fines. A major concern is a category of polymeric contaminants known as “stickies.” This includes pressure sensitive adhesives, hot melts, waxes, wet-strength residuals, asphalt, pitch, inks, toners, and other resins added to paper for various purposes. “Stickies” may not only result from contaminants added to the paper, but also from fatty acids, rosin acids, and unsaponifiables, that are inherent in the wood fiber content of the recycle stream.

## THE RECYCLE PROCESS

The nature of the operation for recycling paper varies from mill to mill and depends on the product being produced and the material source. In general, they can be categorized as either being recycle plants or deinking plants. The difference is that in addition to the operations normally found in a recycle plant, a deinking plant will contain a flotation deinking process and probably a bleaching operation.

A recycle or deinking plant is, fundamentally, a pulping operation followed by a separation process. The basic steps of the process are block diagrammed in Figure 2. Figure 3 is the more complex flow diagram of an actual OCC recycle mill for linerboard (4). This type of brown paper operation generally does not include steps for flotation deinking and bleaching. The separation steps are designed to remove the various contaminants that are inherent in the recycle stream. These contaminants can include baling wire, tape, plastic film, beer cans, pieces of glass, metal objects, sand, Styrofoam, wood chunks, adhesive tape, hot melts, and almost any other material or object that can possibly be mixed in with a bale of recycle paper (and some that may be impossible). Figure 4 is a display of some artifacts found in a bale of mixed paper. They include books, magazines, wire-bound ledgers, rolls of tape, and a complete software kit including manuals, container, and discs.

**FIGURE 2 - THE OPERATIONS IN A DEINKING/RECYCLE PROCESS**



### **Pulping**

Generally, bales of recycle paper are loaded on a conveyor and conveyed to a pulper. Pulpers can either be continuous or batch. Figure 5 is a simplified diagram of a continuous pulper. The agitator is a high shear device designed to break up recycle paper into a pulp form. This includes well-bonded paper structures such as wet-strength papers. The extractor plate at the bottom of the pulper is a foraminous plate that lets defibered pulp discharge from the pulper, but retains large undefibered chunks and objects. These larger pieces either stay in the pulper until broken up enough to pass through the extractor plate or they are washed into a detrashing well. A detrasher is a coarse screen type of device that separates large pieces into a waste discharge stream and recovers good fiber. Some of these devices include an additional pulping function to recover additional fiber.

In many pulper operations, baling wire is sent with the bale into the pulper. A ragger is used to remove the wire from the pulper by twisting the wire into a large rope like structure and continuously screwing this rope out of the pulper. Rope, string, tape, plastic film and other large flexible contaminants are also removed with the ragger.

### **The Separation Operations**

The separation operations remove various particulate matters from the recycle stream. Figure 6 is an indication of the particle size range for the various separations. Note that for the smallest particle size range ( $<10\ \mu\text{m}$ ), a

significant percentage (up to 25%) is not removed even by washing. These small particles can agglomerate and build-up in the paper machine system.

**Cleaning.** Cleaners are centrifugal hydrocyclone devices that separate particles by density as well as by size. A typical cleaner is generally a conical-shaped pressure vessel where pulp slurry enters tangential to the maximum diameter. The cyclone, so formed, forces heavy particles toward the wall of the cleaner, where they are directed to the bottom or narrow portion of the cleaner vessel and discharged. Light particles are directed toward the center of the cyclone and move upward to be discharged at the top of the vessel.

Cleaners are designed to reject either heavy particles or light particles. A forward cleaner is the type of cleaner that rejects heavy particles at the bottom and accepts the light cleaned fraction at the top. A reverse cleaner does just the opposite; it accepts the heavy stream emerging from the bottom and rejects the light particle contaminants at the top. A through flow cleaner acts like a reverse cleaner in that it rejects light particles and accepts the heavier fibers. However, both accept and reject streams exit at the bottom of the cleaner. Figure 7 (6) diagrams and provides operating characteristics for the three types of cleaners discussed above.

Forward cleaners are also classified as high density, medium density, and fine forward, depending on the density of particle to be rejected. High density cleaners are most often used to remove sand, glass, metal, and other high density particles that emerge from the pulper.

Cleaning systems are also staged: primary, secondary, tertiary, etc. The rejects from one stage will go to the next stage for further cleaning.

**Screens.** Screens are used to screen out larger particles from the fiber slurry. They come in a variety of shapes and forms. There are vibrating flat screens, sidehill screens and pressure screens. Modern recycle plants rely heavily on pressure screens since they can be pressurized to increase flow rate and efficiency. A pressure screen contains a cylindrical screen basket. Conventional baskets contain either holes for coarse screening or slits for fine screening. These are diagrammed in Figure 8 (6). Slitted screens can be produced with slits as low as .004 in. in width.

**Flotation Deinking.** Flotation deinking is the fundamental operation for removing ink and toner particles in printed paper recycle. The air bubbles float the particles to a foam layer at the top of the slurry where the foam with particles is removed. A simple flotation unit is diagrammed in Figure 9. In recent years pressurized flotation cells, called Pressurized Deinking Modules (PDM) (7), have come in vogue. These are horizontal tube-like separators with the foam layer coming off at the top and the deinked slurry exiting at the bottom.

**Washing.** Washing removes small contaminant particles from a fiber slurry by diluting and mixing the slurry in water and then filtering. Presumably the contaminant particles will go with the water. In Figure 10 (5) the washer is a drum washer. The filtered fiber forms a mat on the wire-covered drum filter and is removed from the roll with a doctor. Very often a couch roll is used to help remove the mat. In Figure 10, spray nozzles are used to assist the washing process. Surfactants are used to enhance the washing process.

Figure 11 is another type of washer called a Double Nip Thickener (8). It sprays the slurry into the inside nip where a porous fabric belt meets a breast roll. The squeezing action between the belt and the roll forces the wash water out of the fabric. The washed mat on the inside of the fabric is removed by a couch roll into a discharge conveyor.

### The Other Operations

Other operations in a recycle or deinking plant are not intended to separate contaminants, but rather to better prepare the fiber for downstream or paper machine operations. Included in these operations are bleaching, fractionation, thickening, dispersion, and high-density storage.

**Fractionation** Fractionation is a screening or filtration operation that splits a fiber stream into two fractions, usually a long and a short fiber fraction. The advantages (9) of doing this are as follows:

- a. The fractions can be treated separately, such as refining, and then recombined for optimization of pulp properties.
- b. The fractions can be sent to different paper machines in a multimachine mill.
- c. The fractions can be used in different plies of a multiply paper machine. This option has become attractive for some mills that produce multi-ply linerboard.

**Bleaching** Bleaching (10) is necessary if high levels of brightness are desired for the product, for example magazine and newsprint grades. Bleach can be added directly to the pulper or to bleaching towers. The most commonly used bleaching agents are hydrogen peroxide and sodium dithionite.

**Thickening** Thickening and washing are related operations in that both use similar equipment to remove water from a fiber slurry. The difference is that washing is also intended to remove contaminant particles from the slurry, whereas thickening serves to increase consistency for subsequent processing (such as high density storage) and minimize water handling capacity. Smook (11) has identified a number of equipment pieces used to thicken fiber slurries. These include drum filters, multidisc filters, screw extractors, and various press designs.

**Dispersion** Dispersion (or kneading) deals with contaminants by breaking them up into small particles so that their effect in the paper product is minimized, or so that they are more readily removed in a subsequent washing step (12). Dispersers often look like disc refiners. Pulp passes through a gap between a rotating and a stationary disc. Kneaders (Figure 12) are like two parallel screws that work the fiber and contaminants between them.

**High-Density Storage** High-density storage tanks are large, vertical, and cylindrical storage tanks designed to store large quantities of pulp at high consistency (5-20%). These tanks bevel inward at the bottom into a controlled agitation zone where the pulp is agitated and diluted for pump-out (11).

## **Paper Machine**

The whole purpose of a recycle or deinking plant is to prepare the fiber in such a way so that it can be used for making paper. Nevertheless, there are problems in recycle streams that carry on to the paper machine. The fundamental ones are stickies, drainage, and loss of paper properties.

**Stickies** The problem of stickies have already been discussed above. Despite all the efforts of the recycle or deinking plant, some stickies do penetrate through the system. Many of these are probably stickie particles that are too small (1 - 5  $\mu\text{m}$ ) to be separated with 100% efficiency. However, the contaminants in the recycle stream are not the only source of stickies. The lignins, rosins and other extractables in the wood pulp fibers have been a source of stickies, probably since paper was invented. If the recycle mill is part of an integrated operation that includes a virgin fiber mill, then the virgin fibers are also a suspect source of stickies.

Recycle plant and wet-end chemicals and secondary effects are a very significant source of stickies. Some wet-end chemicals such as polyacrylamides and viscosity modifiers can in themselves be a very serious cause of stickies if not properly processed. Interactions between chemicals, wood extracts, and recycle contaminants can contribute to formation of stickie materials in process. Agglomeration and scaling of deposits on vessel and pipe walls can form large stickie aggregates from particles that were initially well dispersed. Fabric-cleaning compounds such as solvents when released into white water systems can plasticize stickies and make them stickier (13).

There are several chemical strategies employed for control of stickies. Many of these are applied in the recycle plant before the paper machine, as far back as the pulper. Fogarty (15) describes five such strategies as follows:

**Dispersion** - Chemicals that enhance the mechanical and thermal processes to disperse contaminants as discussed in C.5 above.

**Detackification** - Chemicals that make the stickie particle nontacky or nonsticky.

**Cationic polymer** - This refers to retention systems that try to retain the small stickie particles in the web of the paper that is being formed, and prevent them from entering the white water recycle system.

**Passivation** - Barrier chemicals and/or release agents that are applied to paper machine fabrics and roll surfaces to inhibit stickie deposition.

**Solvent** - Cleaning chemicals used to clean fabrics and roll surfaces by dissolving the stickie contamination.

**Drainage** Drainage problems are primarily caused by fines that are inherent in the recycle stream. They are not limited to the paper machine, but also create difficulties in deinking/recycle plant operations such as washing, thickening, and screening. Flocculants and coagulants are often used to enhance drainage of a recycle fiber furnish. However, as the recycle content of paper mill furnishes increases from year to year and as fibers are recycled over and over more often, the level of fines will continually increase. New strategies will have to be developed for dealing with fines and possibly their separation from recycle process streams.

**Paper Properties** A deep concern for the papermaker is the maintenance of paper properties even as the level of recycle increases. Contaminants in the recycle stream will cause attribute defects such as oil spots, specks, holes, tearouts, et al. Other properties such as strength, brightness, friction, printability, surface smoothness et al, become more difficult to maintain.

Recycling of a fiber deteriorates its quality. It becomes shorter and fiber fines segments break off. In addition, hornification sets in, that is, the shrinkage and collapse of the cell wall structure due to successive drying and rewetting. Figure 13 illustrates how successive recycles deteriorate strength (breaking length) properties (16). At the 50% level of recycle it can be calculated that the average number of recycles for a fiber will be one, and the maximum will be six (16). Understandably, the average and maximum number of fiber recycles increase as the level of recycle increases.

Mechanical refining and chemical strength additives such as starch and polyacrylamide are two ways of dealing with strength loss in paper due to recycling. Technical challenges of the future will have to deal with maintenance of paper properties as the level of recycle increases and the number of fiber recycles increase.

## CONCLUSIONS

The paper and paperboard industry in the United States has made very good progress in recycling paper back into paper and paperboard products. The level of recycle has almost doubled in the past 10 years. Distribution systems and grade structures for recycle paper have been established and will continue to be further developed in the future. Mini mills are being built near urban centers to take advantage of the large quantities of recovered paper being generated. Some quality criteria for recycle paper has been established, however, quality concerns will continue to be a long-term problem, particularly as the level of recycle increases. Process and chemical strategies for dealing with recycle fiber quality and separation of contaminants are in place and continually being improved upon. Economics is the major factor in the development of recycle paper as an alternative fiber source.



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FIGURE 4

ARTIFACTS FOUND IN A BALE OF MIXED PAPER WASTE



**Figure 5**

# **Recycling of Recovered Paper Pulping Process**

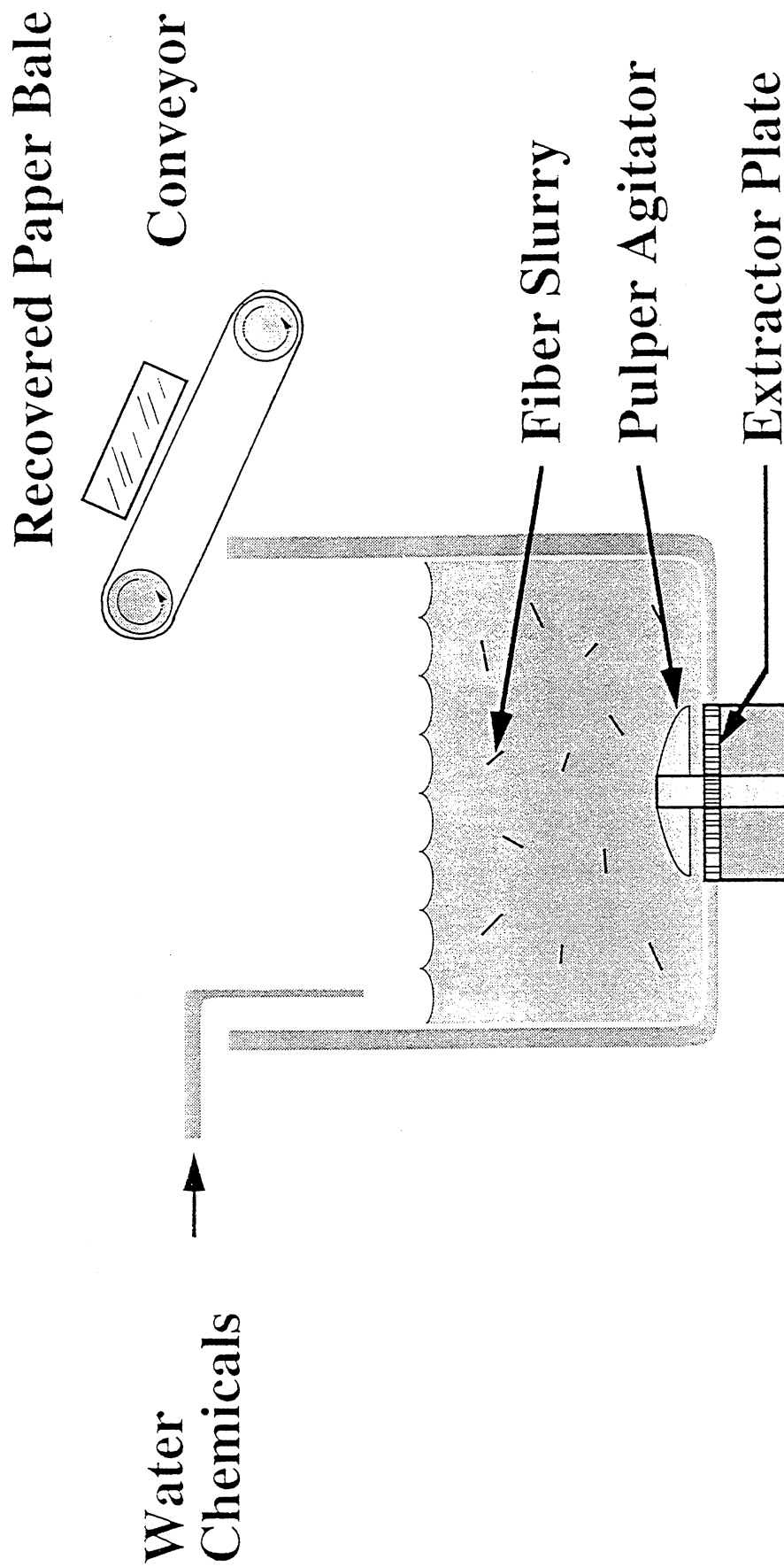
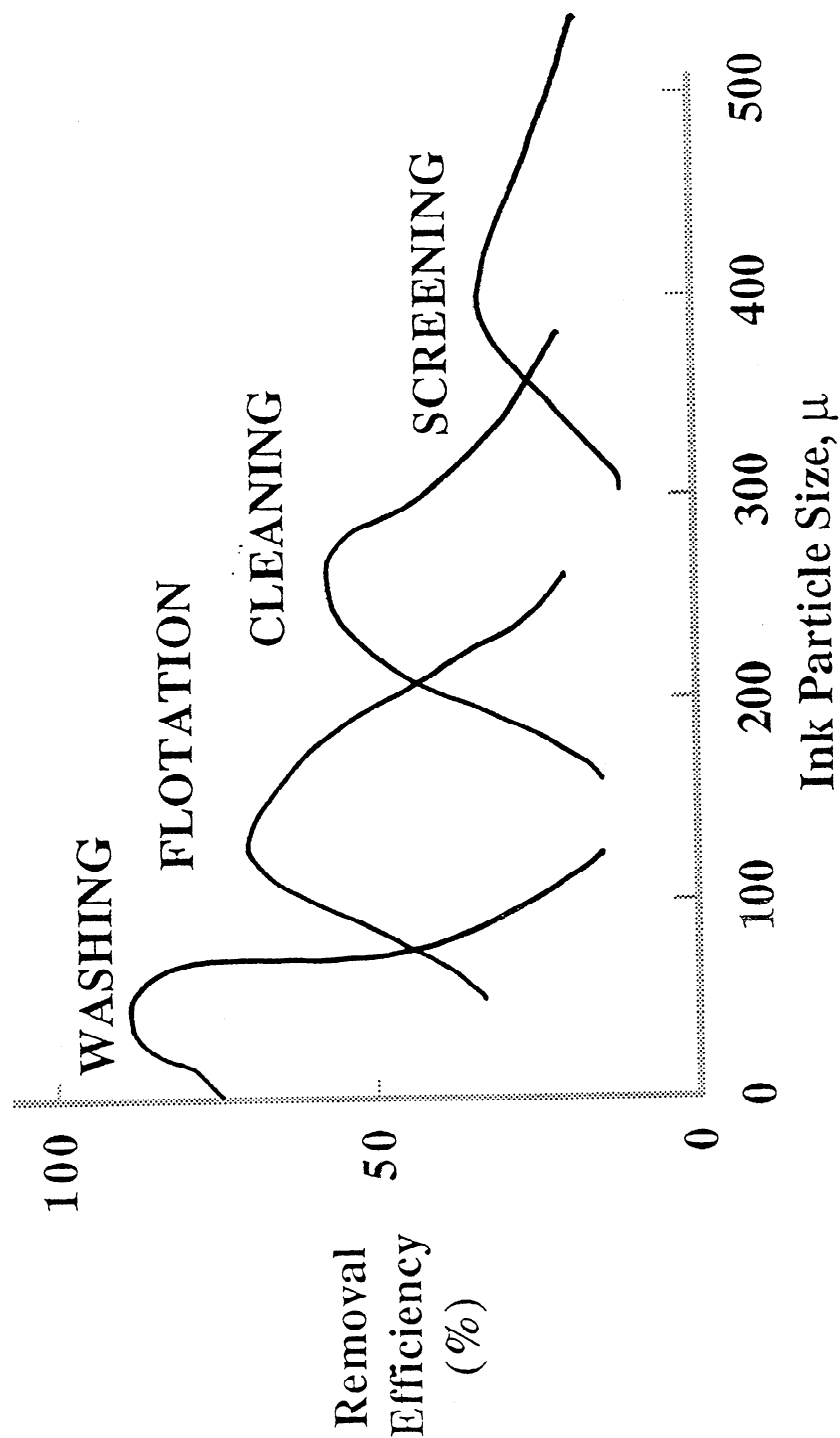


Figure 6

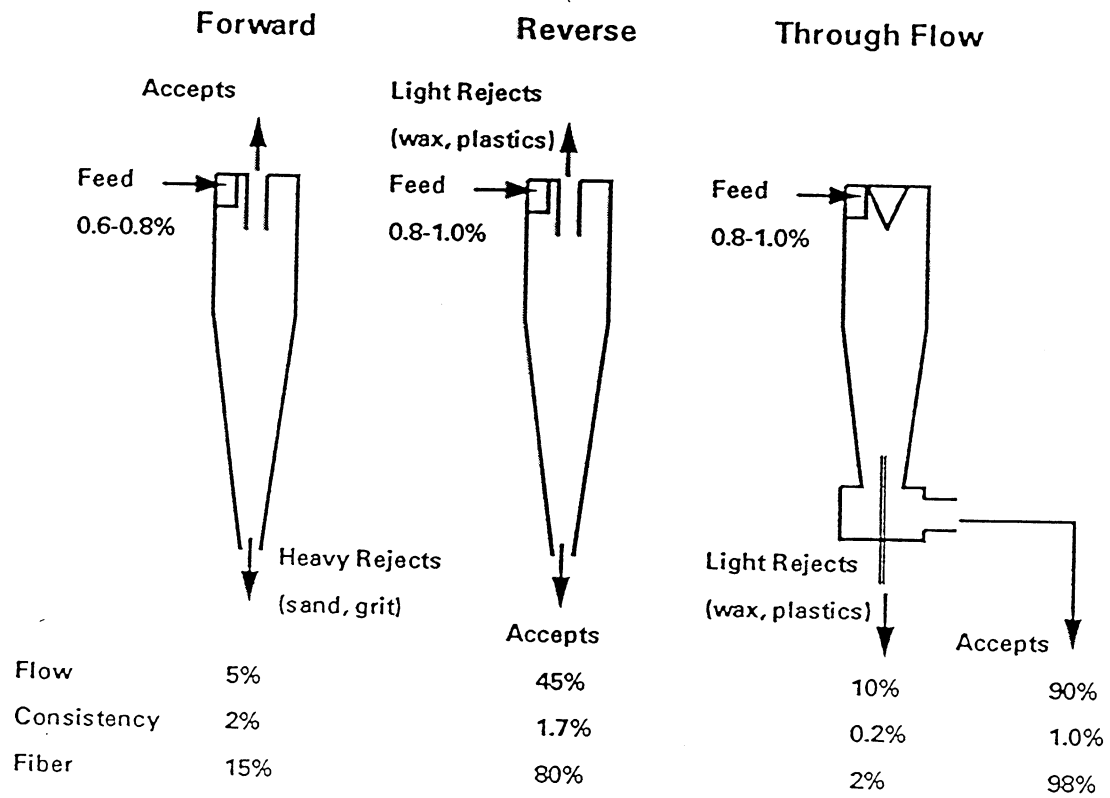
# Contaminant Removal Processes

Deinking Efficiency and Particle Size



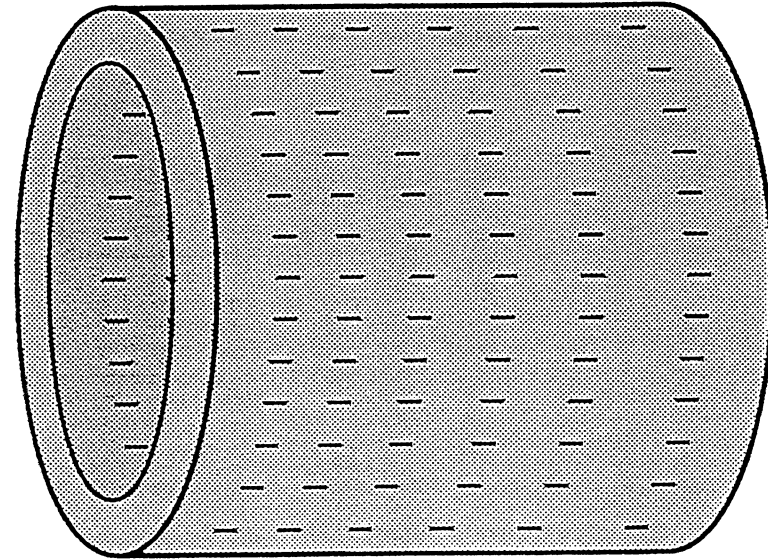
# Figure 7

## Recycle Plant Cleaning Devices

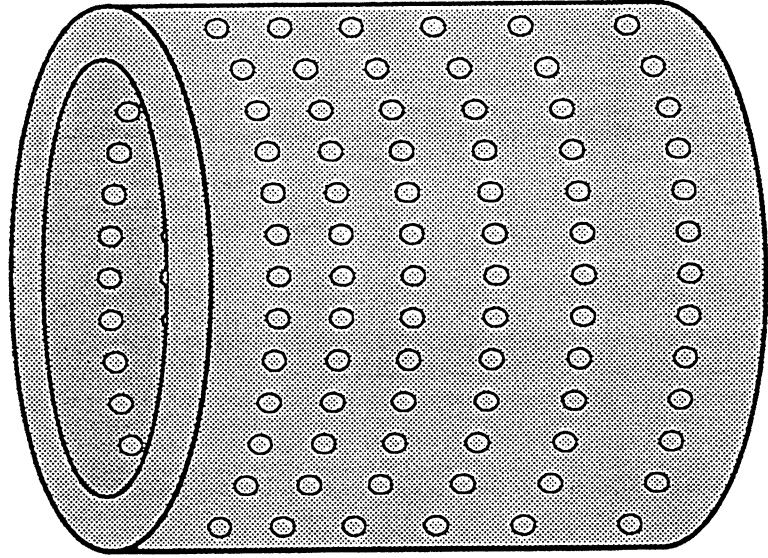


**Figure 8**

# Conventional Screens



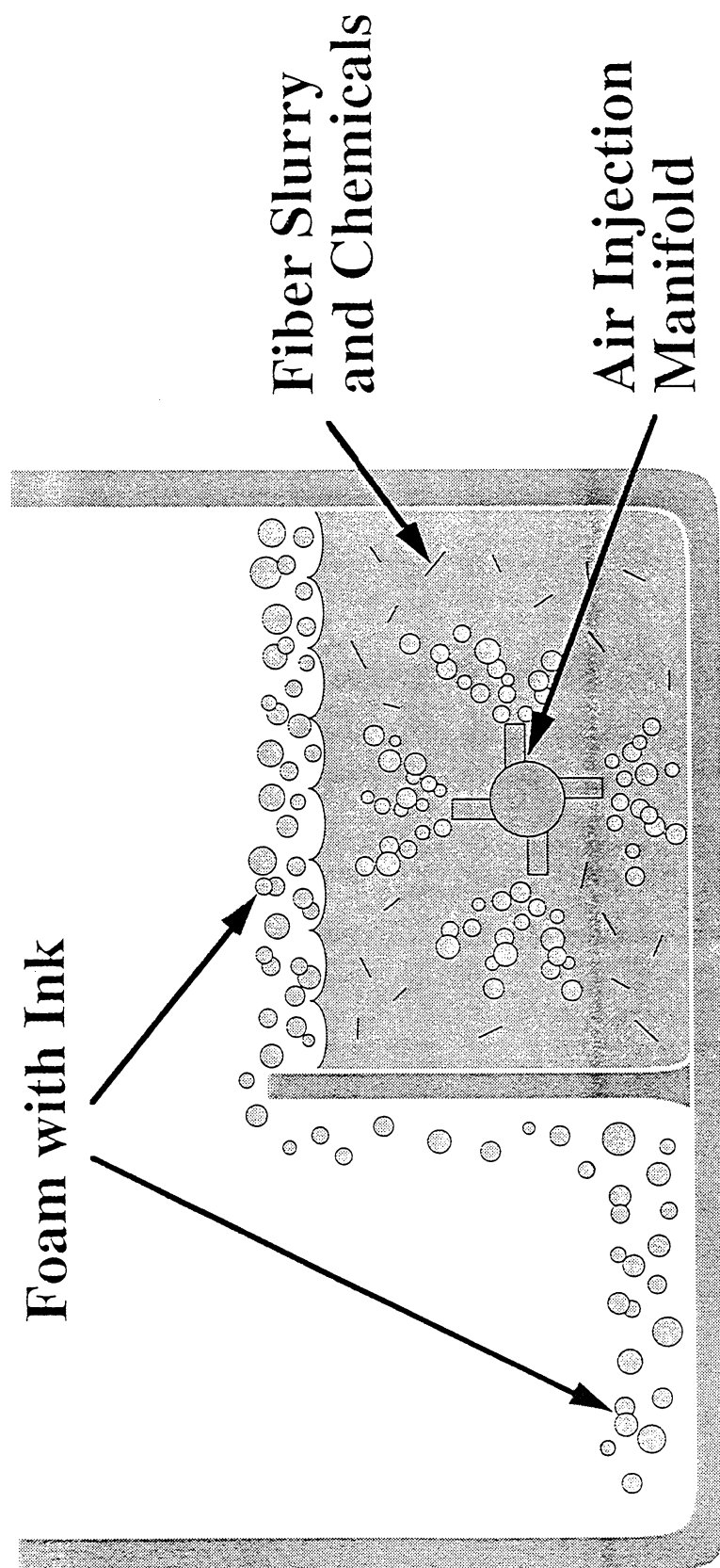
**Slits**



**Holes**

**Figure 9**

# **Recycling of Recovered Paper Flotation Deinking Process**





**Figure 10**

# **Recycling of Recovered Paper**

## **Washing Process**

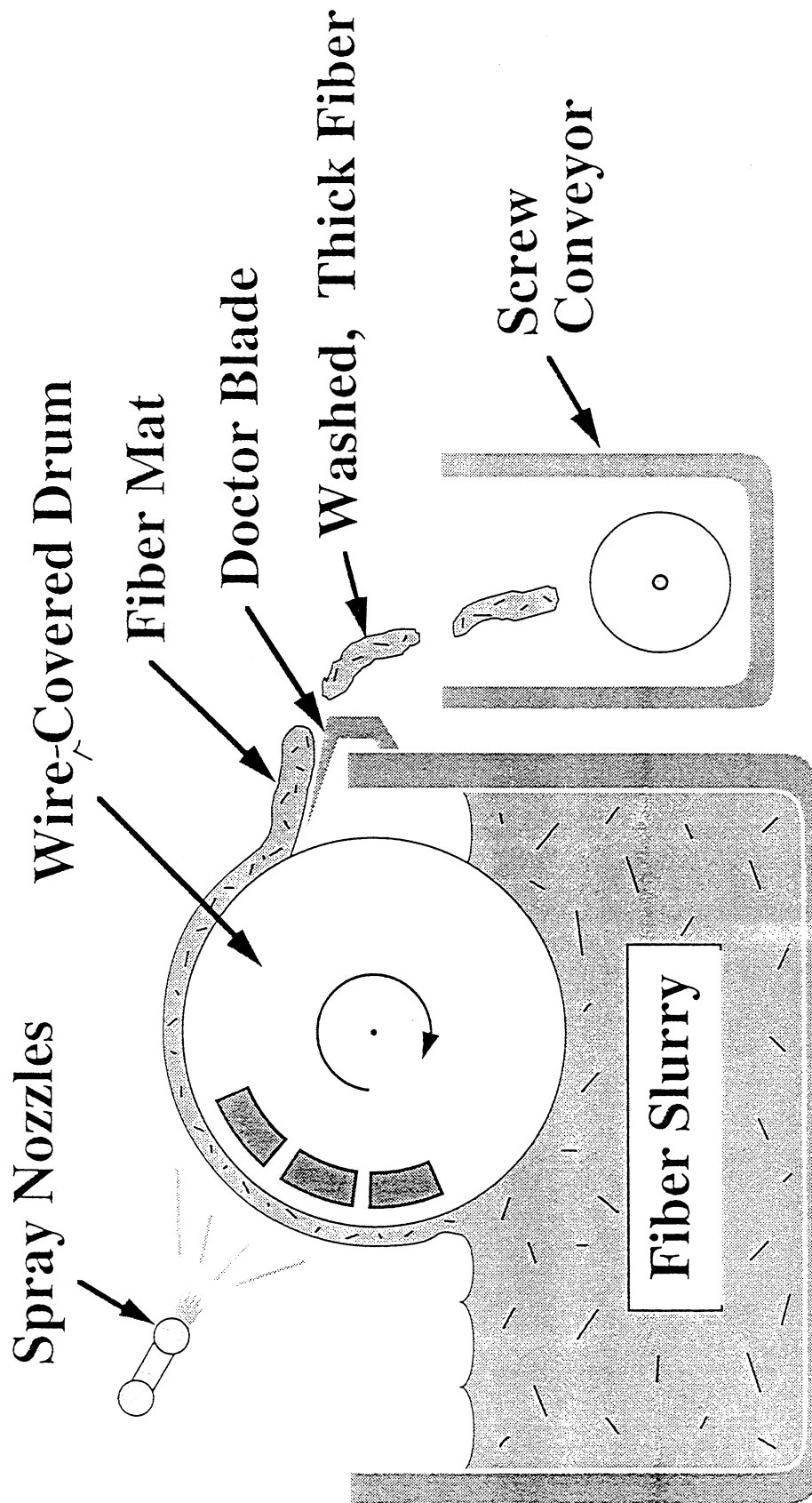
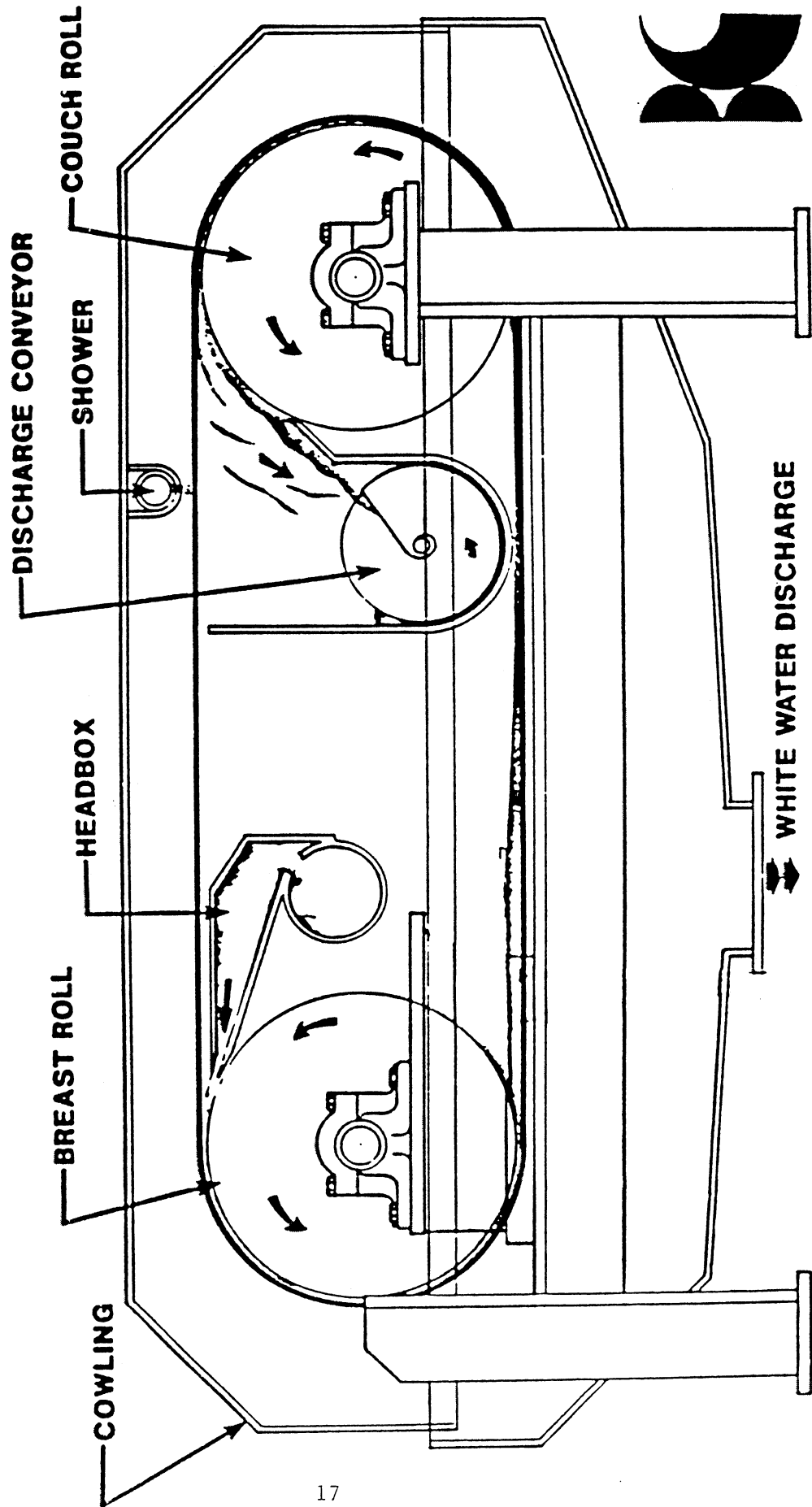


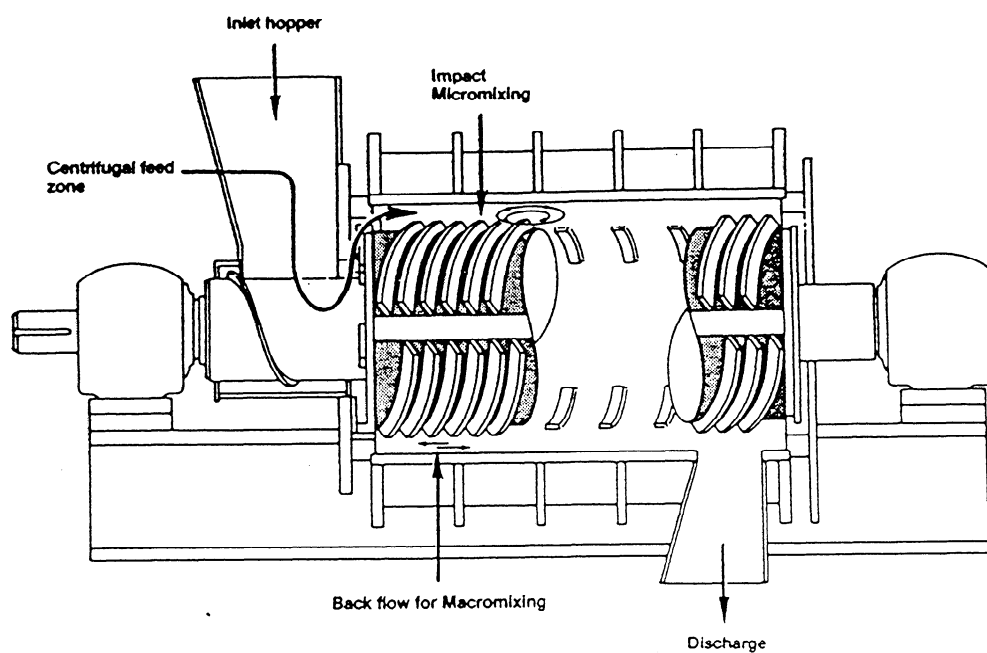
Figure 11

## DOUBLE NIP THICKENER



**Figure 12**

**Kneader Dispersion Machine**



**Figure 13**

